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by

R. A. Hamilton.

(Meteorological Office)

AIR MINISTRY

METEOROLOGICAL RESEARCH COMMITTEE

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Introduction

The object of this note is to describe and discuss the method used in determining the values of relative humidity, vapour pressure etc. which will be published in the meteorological tables for Britannia Sø, the main base of the British North Greenland Expedition in Dronning Louise Land (77°09'N, 23°36'W, altitude 231 m.).

The annual range of temperature was from around - 40°C to about +16°C. The lowest temperatures occurred during calm periods during the winter when hoar frost deposits indicated that the relative humidity was high. The hoar frost deposits were usually light, rarely heavy, and fog occurred only once during the two winter periods. During the winter the calm clear periods alternated with windy periods during which dry air poured downwards from the inland-ice to the coast, with a low relative humidity and dew point.

The difficulties experienced arose through the lack of an absolute instrument for measuring humidities at low temperatures. The Dobson-Brewer frost point hygrometer which had been used by the Norwegian-British-Swedish Antarctic expedition had given trouble and could not be modified in time to be taken by B.N.G.E. The modifications were carried out and the instrument was dropped by parachute to the expedition in 1953 but was damaged and could not be repaired.

Instruments in use

The instruments used were:-

(a) Dry-and wet-bulb hygrometer. This will be referred to as D.W.B. even when an ice-bulb was used. Normally a whirling psychrometer was used, but in the spring when temperatures were higher the normal dry- and ice-bulb thermometers in the screen were used when there was appreciable wind. The bulb was painted with ice half an hour or so before reading.

The D.W.B. is of little use at temperatures below -15°C, as the depression of the ice-bulb is so small that it cannot be read with any degree of accuracy on the small thermometers in use. In the conditions which frequently occurred, viz. strong katabatic winds of low relative humidity and temperatures above -15°C, a determination of relative humidity could be made which was probably correct to 5% - assuming, that is, that the tables used for determining the water vapour pressure from readings of the ice-bulb were correct. The tables used are from the 1951 edition of Smithsonian Meteorological Tables, Table 98. Values of saturation vapour pressure over water and over ice are derived from Tables 94 and 96 of this volume.

(b) Hair hygrograph. This was a normal M.O. pattern. The trace shows that it responds well to change of humidity, but it cannot, of course, be regarded as an absolute instrument. The intention was to calibrate the hygrograph so that the relative humidity at the standard hours could be deduced from the trace and the calibration - which might vary from month to month.

/(c)

(c) Lithium chloride hygrometer. This will be referred to as the L.C.H. This instrument was made by the Meteorological Office, but is commercially made under the name "Dewcel" and is patented. Two coils are wound close to one another, without making contact, on a thermometer bulb and the whole is painted with lithium chloride, a hygroscopic substance. When the lithium chloride is wet, it conducts and a current can be passed between the two coils. This current heats the thermometer and lithium chloride coating and the temperature rises until the lithium chloride becomes dry and ceases to conduct. The temperature at which this occurs, is that at which the vapour pressure of the lithium chloride is equal to the ambient atmospheric water vapour pressure, and is measured by the thermometer. A calibration curve (experimentally determined at Blue Hill) was provided but it was not suggested that it was absolutely correct and the intention was not as much to regard the L.C.H. as an instrument of precision but one which was to be studied and perhaps calibrated. Subsequently a second calibration curve has been supplied by Messrs Foxbro Yoxall, the manufacturers of the "Dewcel", which differs appreciably from the original calibration curve.

Comparison of hair hygrograph with D.W.B.

The instruments were installed in the Stevenson screen late in October. The hair hygrograph had been set in the normal way, viz. the hairs were wetted indoors and the pen set to read 95%. During the period Nov.-Dec. 1952 measurements were made with the D.W.B. whenever possible. These are set out in Table 1 with the computed values of vapour pressure, relative humidity and dew point. The computed values of the relative humidity, R, are compared with the hygrograph readings, H, in Table 2. Bearing in mind the small depressions of the ice-bulb and the consequent rather large error in the determination of R, the agreement can be seen to be fairly good with no apparent zero error of the hygrograph. There is some uncertainty in the value of the constant used in the computations of humidity from ice-bulbs but if the one which was used is correct, then it appears that the hygrograph, if set up in the normal manner at room temperature, will read correctly at temperatures down to -10°C to -15°C.

During these two months, November and December 1952, during calm clear weather when hoar frost was deposited (fairly lightly) on the roof of the screen the hair hygrograph recorded values mainly in the range 90 to 96% (see Table 3). It has frequently been stated that at temperatures below 0° the hair hygrometer measures humidities relative to water vapour, and in the belief that during these calm periods with hoar frost depositing on the screen, the relative humidity relative to ice must be approaching 100%, a zero adjustment was made (in two stages) so as to give a hygrograph reading more closely in accord with the presumed relative humidity relative to water. At -30°C the R.H. relative to water is 75% when relative to ice it is 100%.

This, unfortunately, began a series of adjustments to the hygrograph in an effort to agree with the presumed high humidity value, the D.W.B. and the L.C.H. which continued until temperatures above 0°F were experienced in May. Thereafter no more zero adjustments were made. The hygrograph readings in May agreed well with the D.W.B. and by that time the sum of the zero adjustments amounted to only 1% - a fortuitously good agreement as the adjustment had not always been made in steady conditions and the error in measuring and adjustment must have been as much as 1%. The dates and magnitudes of the zero adjustments together with the accepted scale correction for each period between adjustments is shown in Table 4.

/Table 1

Table 1 Dry- and ice-bulb hygrometer measurements

GMT/Date	Dry t°C	Wet t'°C	t-t'	Δe_{1000} mb. Tab 98	p mb.	Δe mb.	e' mb. Tab 96	e mb.	Sat. e water mb. Tab 94	R.H. water %	D.P. °C Tab 94
Nov. 1952											
1200/16	-5.9	-7.8	1.8	1.18	994	1.17	3.15	1.98	3.92	51	-14.6
1140/17	-6.9	-9.2	2.2	1.48	983	1.45	2.79	1.34	3.63	37	-19.2
1200/17	-7.2	-9.4	2.2	1.48	983	1.45	2.73	1.28	3.56	36	-19.8
1300/17	-6.1	-8.1	1.9	1.27	983	1.25	3.08	1.83	3.87	47	-15.5
1500/17	-5.0	-6.7	1.7	1.09	982	1.07	3.48	2.41	4.21	57	-12.2
2100/17	-5.0	-7.8	2.8	1.82	982	1.78	3.16	1.38	4.21	33	-18.9
0930/18	-10.0	-11.9	1.9	1.26	990	1.25	2.18	0.93	2.86	33	-23.4
1730/18	-11.1	-12.5	1.4	0.90	992	0.90	2.08	1.18	2.62	45	-20.7
1800/18	-10.3	-11.7	1.4	0.94	992	0.93	2.23	1.30	2.80	46	-19.6
1030/19	-7.1	-8.8	1.7	1.09	989	1.08	2.89	1.81	3.59	50	-15.7
1300/20	-4.2	-7.2	3.1	1.99	981	1.95	3.31	1.36	4.49	30	-19.1
1600/20	-5.8	-8.1	2.2	1.44	980	1.41	3.08	1.67	3.95	42	-16.6
1340/24	-12.8	-13.9	1.1	0.72	985	0.71	1.83	1.12	2.29	49	-21.3
1300/25	-11.1	-12.7	1.6	1.02	990	1.01	2.04	1.03	2.62	39	-22.3
1400/27	-13.3	-14.4	1.1	0.72	990	0.71	1.74	1.03	2.19	47	-22.3
Dec. 1952											
1140/1	-10.3	-12.2	1.9	1.26	980	1.24	2.13	0.89	2.80	32	-23.9
1200/10	-12.8	-13.9	1.1	0.72	991	0.71	1.83	1.12	2.29	49	-21.3
1300/30	-9.4	-11.1	1.7	1.09	1000	1.09	2.35	1.26	2.99	42	-19.9
Jan. 1953											
1130/2	-2.8	-5.8	3.1	1.99	980	1.95	3.74	1.79	4.98	36	-15.8
1200/9	-8.9	-10.6	1.7	1.09	982	1.07	2.47	1.40	3.12	45	-18.7
1400/27	-7.0	-7.7	0.7	0.44	975	0.43	3.19	2.76	3.62	76	-10.5
1300/29	-13.3	-13.9	0.6	0.36	984	0.35	1.83	1.48	2.19	68	-18.1
April 1953											
1220/2	-9.4	-11.4	1.9	1.26	999	1.26	2.29	1.03	2.99	34	-22.3
1140/6	-10.0	-11.4	1.4	0.91	990	0.90	2.29	1.39	2.86	49	-18.8
1740/22	-2.8	-5.3	2.5	1.63	1000	1.63	3.92	2.29	4.98	46	-12.8
1140/23	-1.4	-2.8	1.4	0.91	1002	0.91	4.84	3.93	5.52	71	-5.9
1440/23	-0.6	-1.7	1.1	0.73	1002	0.73	5.32	4.59	5.86	78	-3.9
1730/26	-2.2	-4.4	2.2	1.46	1004	1.46	4.20	2.74	5.19	53	-10.6
2120/26	-4.2	-5.4	1.4	0.91	1004	0.91	3.86	2.95	4.49	66	-9.6
1140/27	-1.4	-4.4	3.1	2.00	1002	2.00	4.20	2.20	5.51	40	-13.3
1830/29	-6.4	-7.7	1.3	0.84	995	0.84	3.19	2.35	3.79	62	-12.5
1200/30	-8.1	-8.9	0.8	0.51	995	0.51	2.86	2.35	3.32	71	-12.5
1730/30	-8.2	-8.9	0.8	0.51	993	0.51	2.85	2.34	3.30	71	-12.5
May 1953											
1140/1	-4.2	-4.4	0.3	0.19	989	0.19	4.20	4.01	4.49	89	-5.7
1740/1	-1.2	-1.8	0.6	0.37	989	0.37	5.27	4.90	5.58	88	-3.0
2100/1	-1.2	-2.2	1.0	0.66	989	0.65	5.08	4.43	5.58	79	-4.4
0540/2	-0.4	-1.4	0.9	0.62	988	0.61	5.44	4.83	5.92	82	-3.2
1740/2	+0.1	-1.0	1.1	0.73	988	0.72	5.62	4.90	6.15	80	-3.0
2100/2	-1.2	-2.2	1.0	0.66	988	0.65	5.08	4.43	5.58	79	-4.3
1140/3	-2.0	-3.4	1.4	0.94	988	0.93	4.58	3.65	5.28	69	-6.9
1740/3	-1.8	-3.1	1.3	0.85	988	0.84	4.74	3.90	5.36	73	-6.0
1140/4	-3.1	-5.0	1.9	1.25	990	1.24	4.01	2.77	4.86	57	-10.4

Note $\Delta e = \frac{p}{1000} \Delta e_{1000}$

$e = e' - \Delta e$

/Table 2

Table 2

Comparison of hair hygrograph readings (corrected) with determinations of relative humidity by the dry-and-ice-bulb hygrometer

R = Relative humidity from Table 1.
H = Hygrograph reading corrected for zero error.

GMT/Date	R	H	R-H	GMT/Date	R	H	R-H	GMT/Date	R	H	R-H
1952	%	%	%	1952	%	%	%	1953	%	%	%
November				December				April			
1140/17	37	38	-1	1140/1	32	40	-8	2120/26	66	72	-6
1200/17	36	37	-1	1200/10	49	51	-2	1140/27	40	36	4
1300/17	47	36	11	1300/30	42	54	-12	1200/30	71	74	-3
1500/17	57	34	23					1730/30	71	69	2
2100/17	33	33	0	1953							
0930/18	33	27	6	April				May			
1030/19	50	38	12	1220/2	34	34	0	1140/1	89	83	6
1300/20	30	32	-2	1140/6	49	52	-3	1740/1	88	77	11
1600/20	42	41	1	1740/22	46	48	-2	0540/2	82	83	-1
1340/24	49	44	5	1140/23	71	47	24	1740/2	80	76	4
1300/25	39	44	-5	1440/23	78	49	29	2100/2	79	76	3
1400/27	47	50	-3	1730/26	53	57	-4	1740/3	73	76	-3

N.B. A few cases have been omitted, when the hygrograph indicated that the humidity was changing rapidly.

The disagreement at 1300/17 and 1500/17 is probably due to evaporating of the ice-bulb, a source of error which was watched in later measurements.

Comparison of hair hygrograph readings (corrected) with determinations of relative humidity by the dry-and-wet-bulb hygrometer

R = Relative humidity determined by dry-and-wet-bulb hygrometer.
H = Hygrograph reading corrected for zero error.

GMT/Date	R	H	R-H	GMT/Date	R	H	R-H	GMT/Date	R	H	R-H
1953	%	%	%	1953	%	%	%	1953	%	%	%
May				July				August			
1800/6	40	36	0	1200/20	32	36	-4	0530/5	41	35	6
2100/6	66	65	1	1800/20	29	30	-1	1200/6	51	51	0
0600/7	40	37	3	2100/20	30	32	-2	1800/8	69	71	-2
0900/7	58	68	-10	2300/20	31	31	0	1130/13	39	39	0
1200/7	59	63	-4	0600/21	26	27	-1	1130/14	40	36	4
1300/7	62	63	-1	1800/21	38	33	4	1130/16	35	36	-1
1500/7	55	58	-3	2300/21	52	43	9	1730/18	32	34	-2
1800/7	62	64	-2	1800/22	58	61	-3	1730/19	72	72	0
1200/25	39	41	-2	2100/22	65	65	0	1730/22	56	55	1
1500/25	39	39	0	1200/23	52	45	7	1130/27	28	31	-3
1800/25	34	37	-3	2300/23	39	38	1	0900/28	31	39	-8
0900/26	68	59	9	1200/24	33	27	6	0900/29	44	48	-4
1200/26	76	62	14	1200/25	40	37	3	0600/30	63	71	-8
1800/29	19	18	1	2300/25	37	39	-2	1730/31	51	47	4
				0600/26	42	41	1				
July				1200/28	49	51	-2	September			
2300/14	33	32	1	1800/29	69	71	-2	1730/1	39	43	-4
1800/15	25	23	2	1800/30	45	42	3	1130/2	54	55	-1
0600/16	74	81	-9	1800/31	40	39	1	0530/4	44	37	7
								1730/4	47	37	10

/Table 3

Table 3

Steady hair hygrograph readings (corrected) at high humidities

1952 GMT/Date	Hoar frost	t °C	H %
November			
0600/2		-19	88
0540/10	x_o	-24	91
0540/11	x_o	-24	91
0540/13	x_o	-24	90
0540/17		-18	86
0540/29	x_o	-23	98
0900/30	x_o	-26	96
December			
0900/8	x_o	-24	89
0900/9	x	-22	90
0540/14	x	-25	89
0540/15	x	-27	89
0540/21	x	-27	95
0540/22	x	-27	96
0540/23	x	-28	96
0540/24	x	-30	96
0540/25	x	-29	96
0540/26	x	-28	96
0540/29	x	-25	97

1953 GMT/Date	Hoar frost	t °C	H %
January			
1740/8	x_o	-21	99
0540/12	x	-29	94
0540/13	x	-30	93
0540/14	x	-31	93
0540/15	x	-30	93
0540/22	x	-28	92
0540/23	x	-29	91
0540/24	x_o	-28	91
1200/25	x	-29	94
February			
0540/1	x	-36	88
0540/2	x	-35	89
March			
0540/6		-29	80
0540/7		-29	79
0540/8		-31	78
0540/9	x_o	-31	82
0540/10	x_o	-28	82
0540/14	x_o	-38	83
0540/22	x_o	-31	86
April			
0540/11		-24	96
0540/27		-9	95

In all cases cloud amount $<$ 3/8, wind speed $<$ 3 kt.

At t = -35°: if D.P. = -36° R.H. = 91%; if D.P. = -36.5 R.H. = 86%

At t = -25°: if D.P. = -26° R.H. = 91%; if D.P. = -26.5 R.H. = 87%

At t = -15°: if D.P. = -16° R.H. = 92%; if D.P. = -16.5 R.H. = 88%

The following values of H were recorded on occasions during October, 1953:-

0900/4 H = 93 at -18°C with slight hoar frost
2100/12 H = 88 at -6°C during long period of snow
1200/23 H = 96 at -11°C during blizzard with 80 m. visibility
0530/26 H = 97 at -8°C during blizzard with 100 m. visibility
0900/29 H = 96 at -13°C in fog with hoar frost.

Table 4

Table 4

Hygrograph resettings

		Change	Net change from Oct '52	Accepted scale correction
Initial setting in Oct. 1952		0	0	0
1830/30 Dec.	lower	8	-8	+8
1230/9 Jan.	lower	12	-20	+20
1800/2 Feb.	lower	18	-38	+38
1800/3 Feb.	raise	10	-28	+28
2100/4 Feb.	raise	7	-21	+21
1740/4 Mar.	raise	18	-3	+3
1030/10 Mar.	lower	15	-18	+17
1815/30 Apr.	raise	7	-11	+10
1800/2 May	raise	15	+4	-5
2100/3 May	lower	5	-1	0

The values of H given in Tables 2 and 3 have been corrected for zero adjustment according to the accepted scale correction shown in Table 4. During May, August and September, 1953 the accepted correction was zero, in July a correction of +3 has been added. This gives the best agreement with the D.W.B. but it is felt the amount is too small to be significant. It will be seen from Table 2 that the hygrograph, corrected for zero error, gives good agreement with relative humidity determined by the D.W.B., with no appreciable temperature coefficient, down to temperatures of around -15°C and dew points down to -22°C.

The hair hygrograph in conditions of high relative humidity

An experiment carried out by M.O.16 at Harrow (private communication) on a sample of hair showed that "Down to temperatures of -30°C the hair was found to follow the room temperature calibrations remarkably well if one assumes that the hair responds to R.H. with respect to water with a negligible temperature effect. The effect of temperature on a M.O. type of hygrograph has also been shown to be the same as that of the brass frame used in this experiment".

If then it is accepted that the hair hygrograph measures humidity correctly relative to water, the implication of the B.N.G.E. measurements is that in the free atmosphere hoar frost is not deposited until the air is super-saturated with respect to ice. The assumption that is now made is that hoar frost is deposited when the air is saturated with respect to water.

In order to obtain an approximate measurement of the temperature of the air in contact with surfaces on which hoar frost was being deposited a thermometer was exposed on top of the screen and the temperature of this was measured when a deposit of hoar frost had deposited on it. This temperature, t_o, is given in Table 5,

/Table 5

Table 5

Date 1952	Hoar frost	t	D.P.(W) t_o	e	D.P.(F)
20/12	x	-27.8	-29.0*	0.42	-32.0
21/12	x	-26.9	-28.1	0.46	-31.1
29/12	x	-24.4	-25.5*	0.60	-28.2
1953					
11/1	x	-27.5	-28.9	0.43	-31.8
22/1	x	-28.4	-29.5	0.40	-32.5
31/1	x	-34.4	-36.7	0.19	-40.2
9/3	x_o	-30.0	-31.5	0.32	-34.8

*Estimated

together with the air temperature t. It will be seen that normally $t-t_o$ is between 1.0 and 1.5, and such a difference has been assumed in the two cases when t_o was not measured. If it is assumed that frost is deposited when the air is saturated with respect to water, then t_o is the dew point D.P.(W). If on the other hand t_o is taken as the frost point, then e is the water vapour pressure and D.P.(F) is the corresponding dew point.

The note below Table 3 indicates that when the depression of the dew point is 1 C° to 1.5 C° below the air temperature the relative humidity is 92% to 86%. If, therefore, the assumption that hoar frost is deposited at the dew point is correct, and if the hair hygrograph reads relative humidity relative to water, then the hygrograph should read about 92% for a normal hoar frost deposit, and about 85% for a light deposit. That this is so in the main is shown by the figures in Table 3.

The hygrograph readings during October 1953 on occasions when the relative humidity can be expected to be high are shown at the foot of Table 3. Again the figures are reasonable. The fog on October 29th was the only fog which occurred during the winter half of the year.

The lithium chloride hygrometer

Though the L.C.H. was set up in November 1952 and measurements with it were made at once, it was some time before the initial difficulties were overcome. The commutator did not alternate for equal periods in each direction and it was soon found that the L.C.H. reading oscillated in apparently steady meteorological conditions. Perhaps this would not have occurred if the L.C.H. had been left running continuously, but this was not possible, firstly because its relays interfered with the radio research, secondly because there was a shortage of power after the breakdown of the main generator, and thirdly because the bottle of lithium chloride had been lost in transit and there was no means of recoating the element. It seemed wise, therefore, to keep it at air temperature so as to minimise the rate of sublimation, and to use the L.C.H. only when humidity could be measured concurrently by some other means.

The relays were adjusted on December 19th so that an A.C. ammeter kicked equally for each of the alternate impulses in opposite directions. A long run was made 21/12/52 and Fig. 1 illustrates the behaviour of the L.C.H. whose temperature is plotted against time for a period of about 4½ hours. It will be seen that the period of the oscillation is about half-an-hour, and twice the amplitude of the oscillation of the L.C.H. temperature is about 15 F°, corresponding to a variation of dew point determination of about 5 C°.

/Subsequent

Subsequent runs showed that the period was usually 20 to 40 minutes, but at higher dew points the amplitude was much less.

In making L.C.H. observations the L.C.H. was run for an hour or two, and then readings were taken every 5 or 10 minutes for an hour or so, so that one or two complete cycles were completed. The L.C.H. temperatures were then plotted against time and the value which appeared to represent best the mean of the L.C.H. readings was taken as the L.C.H. temperature: this could be estimated to within about 1 F° corresponding to 0.3 C° in dew point determination.

There is a close relation between the ammeter readings and the L.C.H. temperature. It was found that when the current through the L.C.H. was plotted on the same time scale as the L.C.H. temperatures it too varied in a manner similar to the temperature, the latter reaching its maximum and minimum values soon after those of the former. In unpleasant weather the observer sometimes plotted the ammeter reading indoors and only went outside to read the L.C.H. temperatures when the current had just passed through its extreme values.

That the L.C.H. temperatures oscillated is not surprising as the system of automatic cutting off the heating when the lithium chloride was dry and restarting the current when it became wet is intrinsically oscillatory as is a thermostat. At low temperatures and light winds the oscillation was marked, as is to be expected for at temperatures and dew points around -30°C the L.C.H. temperature is around -15°C. The L.C.H. will, therefore, cool quite quickly when the current ceases and with the water vapour pressure as low as 0.5 mb. it will take some time for enough moisture to be taken up by the lithium chloride to enable it to conduct. At higher temperatures the amplitude of oscillation was much smaller amounting to only about 1 F° at temperatures around freezing point.

Table 6 gives the L.C.H. temperature reading on all occasions, after the commutator adjustment on December 19th, on which a measurement of the dew point was made by another method. The L.C.H. temperature is plotted against the dew point measurement in Fig. 2. The circles are dew points determined by D.W.B., the crosses determinations by hair hygrograph, but excluding cases when the humidity was high, i.e. in cases of cold calm weather. The estimates of dew point in cases of cold calm weather with hoar frost depositing are also shown: the squares are the estimated dew points on the assumption that hoar frost is deposited at the dew point, the triangles are the estimated dew points on the assumption that hoar frost is deposited at the frost point.

In the figure are also plotted other calibration curves (1) that determined experimentally at Blue Hill, (2) that provided by Messrs Foxbro Yoxall and (3) the theoretical curve from the International Critical Tables. It will be seen that the points do not lie around any of these three calibration curves, at higher dew points the plotted points lie close to the theoretical curve and at low dew points they lie closer to it than do either of the other calibration curves. Moreover the squares, the estimated dew points on the assumption that hoar frost is deposited at the dew point, lie well on the best curve drawn through the D.W.B. and the hair hygrograph determinations. That the hair hygrograph points fit with the D.W.B. points is not surprising as it has already been shown that the two sets of determinations were in reasonable agreement, but it must be borne in mind that most of the hair hygrograph determinations were made at temperatures well below -15°C, the lowest temperature at which appreciable depressions of the ice-bulb are experienced. It is satisfactory, therefore, to find these points fitting well with the estimated dew points in cases of high relative humidity, though of course that is no proof that the underlying assumptions are correct, viz. that hoar frost is deposited at the dew point, and that the hair hygrograph has a negligible temperature coefficient.

/For

For the purpose of determining the humidities, vapour pressures etc. given in the meteorological summaries of Britannia Sø the dotted line (B.N.G.E.) in Fig. 2 has been accepted as correct. The implication of this assumption is that:-

(1) In the clear Arctic atmosphere hoar frost is deposited at the dew point.

(2) The constants for computing humidities from ice-bulbs as given in the Smithsonian Tables are correct.

(3) The hair hygrograph functions down to temperatures of -35°C with no appreciable temperature coefficient. (This is confirmed by laboratory experiment).

The value of relative humidity at the synoptic hours is therefore the hygrograph reading, corrected for zero error.

Estimate of the standard error in determining relative humidities

The values of the dew point determined by the L.C.H. according to the accepted calibration curve are shown in the last column of Table 6, headed D.P.(L). These values can readily be compared with the determinations by other methods.

If the calibration is accepted as correct, the standard error of the determinations of dew point by the other methods are:-

By hair hygrograph	1.6 C°
By D.W.B.	1.1 C°
By hoar frost deposit	1.0 C°

The mean value of hygrograph reading H when hoar frost is being deposited (at temperatures around -30°C) was 93% with a standard deviation of 2.8%. For light hoar frost deposit the corresponding figure (at a slightly lower temperature) was 90% with a standard deviation of 5.6%.

At -35°C a standard error of 1.6°C in the dew point involves a standard error of 0.05 mb. in the water vapour pressure. At 40% relative humidity the corresponding standard error in measuring relative humidity is about 6%. At -15°C the corresponding standard errors are 0.24 mb. and 5%.

Thus the standard error in measuring the relative humidity by the hair hygrograph when the dew point is below -10°C is around 5%. When monthly means are calculated the standard error is less than one fifth of the standard error of each observation and is inappreciable. These are random errors. If the accepted calibration of the L.C.H. is in error then the random error is superimposed on a constant error. The appropriate magnitude of the constant error can be estimated as follows.

It must be assumed that the other three calibrations are equally likely to be correct. The standard error of the dew point measurement by the accepted calibration curve is then:-

(a) 2.0 C° when the dew point is -5°C when e = 4.2 mb.
The corresponding error in water vapour pressure Δe is 0.64 mb., introducing an error of ΔR = 15% in the relative humidity.

(b) 2.8 C° at -15°C when e = 1.91 Δe = 0.44 ΔR = 23%

(c) 3.3 C° at -25°C when e = 0.80 Δe = 0.25 ΔR = 31%

(d) 3.9 C° at -35°C when e = 0.31 Δe = 0.08 ΔR = 25%

It will be seen that the random error is small compared with these, so the standard error of the observations arises solely through error in the calibration of the L.C.H. and amounts to 2 to 4 C° in the dew point, and 15 to 30% in the relative humidity. In view of the fact that the accepted calibration lies between the other calibrations and the theoretical curve, it seems likely that the errors are appreciably lower than the estimated standard error quoted above.

/Table 6

Table 6

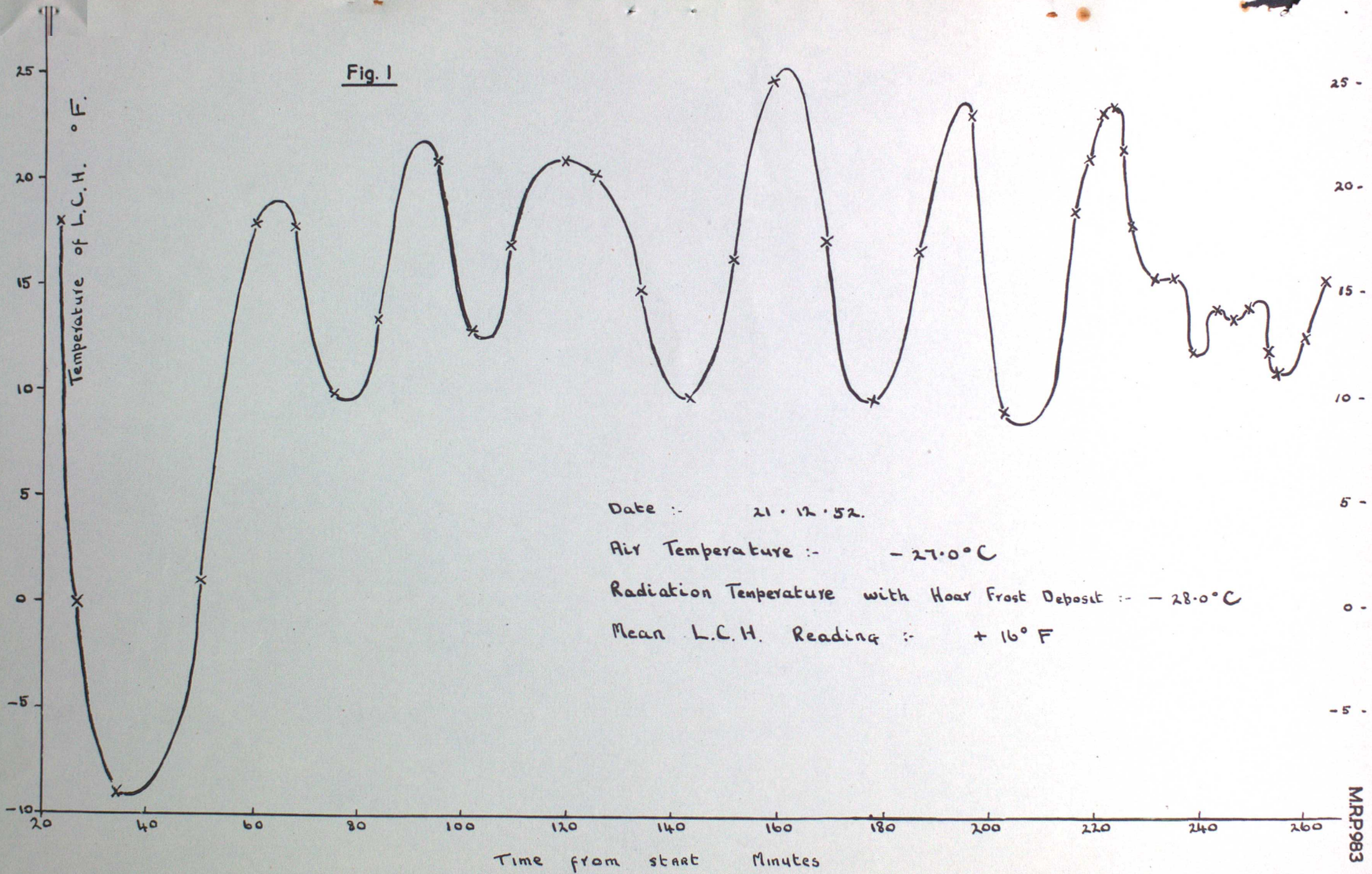
Lithium chloride hygrometer calibration

Key:-

t = air temperature in C°
H = corrected hair hygrograph reading
Sat. e = Saturated water vapour pressure with respect to water at t°C, in mb.
e(H) = Water vapour pressure as measured by hair hygrograph
D.P.(H) = Dew point measured by hair hygrograph, in C°
D.P.(D.W.) = Dew point measured by D.W.B.
D.P.(W) = Estimated dew point assuming hoar frost is deposited at dew point
D.P.(F) = Estimated dew point assuming hoar frost is deposited at frost point
L = L.C.H. reading in F°
D.R.(L) = Dew point measured by L.C.H. according to accepted calibration.

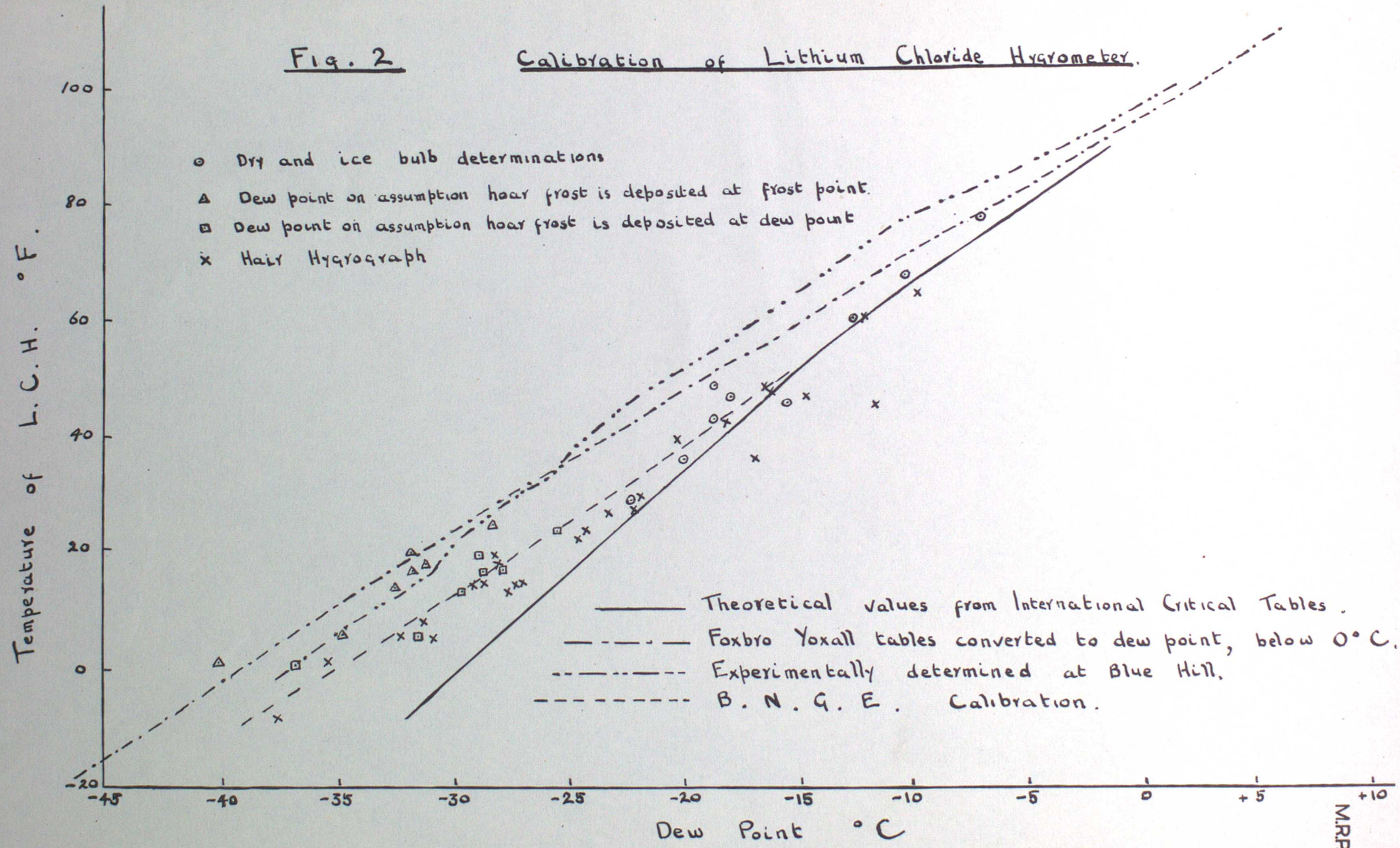
GMT/Date 1952	t °C	H %	Sat. e water mb.	e(H) mb.	D.P.(H) °C	D.P.(D.W.) °C	D.P.(W) °C	D.P.(F) °C	L °F	D.P.(L) °C
December										
1400/19	-27.2	99	0.66	0.65	-27.3				13.5	-29.1
1500/20	-27.8	95	0.62	0.59	-28.3		-29.0	-32.0	18.0	-27.5
1200/21	-26.9	92	0.68	0.62	-27.9		-28.1	-31.1	16.0	-28.2
1300/29	-24.4	100	0.85	0.85	-24.4		-25.5	-28.2	23.0	-25.1
1300/30	-9.4	54	3.00	1.62	-17.0	-19.9			35.0	-20.8
Jan. 1953										
1130/2	-2.8	50	4.97	2.49	-11.8	-15.8			44.5	-17.5
1200/9	-8.9	54	3.12	1.68	-16.6	-18.7			48.0	-16.5
1200/11	-27.5	93	0.64	0.60	-28.3		-28.9	-31.8	14.7	-28.7
1200/22	-28.4	91	0.59	0.54	-29.4		-29.5	-32.5	12.0	-29.9
1400/27	-7.0					-10.5			67.5	-9.6
1300/29	-13.3	89	2.20	1.95	-14.8	-18.1			46.0	-17.0
1200/31	-34.4	89	0.33	0.30	-35.6		-36.7	-40.2	-1.0	-35.1
February										
1100/17	-22.3	60	1.03	0.61	-28.0				16.0	-28.2
1140/20	-22.2	52	1.04	0.54	-29.4				12.5	-29.5
2100/26	-17.8	32	1.51	0.48	-30.5				10.0	-30.6
1500/27	-21.1	50	1.14	0.57	-28.8				16.5	-27.8
March										
1740/8	-30.0	81	0.51	0.41	-32.3				5.0	-32.6
1600/9	-30.0	80	0.51	0.41	-32.3		-31.5	-34.8	4.0	-33.0
1100/10	-26.1	79	0.73	0.58	-28.6				13.3	-29.2
1100/12	-27.8	75	0.62	0.47	-30.9				3.7	-33.2
1330/13	-32.8	77	0.39	0.30	-35.5				-0.5	-35.0
1200/14	-35.3	79	0.30	0.24	-37.6				-10.3	-39.0
1530/15	-27.2	70	0.66	0.46	-31.0				3.1	-33.4
1600/16	-15.6	56	1.82	1.02	-22.4				26.5	-24.0
2200/18	-12.5	52	2.34	1.22	-20.3				38.5	-19.6
1400/21	-20.0	52	1.25	0.65	-27.4				13.0	-29.4
1200/26	-23.9	51	0.89	0.45	-31.3				6.0	-32.2
1500/29	-17.5	54	1.55	0.84	-24.6				21.7	-25.7
April										
1200/12	-9.4	35	3.00	1.05	-22.0	-22.3			28.0	-23.5
1140/6	-10.0	51	2.86	1.46	-18.2	-18.8			42.0	-18.5
1500/13	-11.7	37	2.50	0.93	-23.4				25.4	-24.3
1330/21	-11.7	68	2.50	1.70	-16.4				47.5	-16.5
1440/23	-0.6	49	5.85	2.86	-10.0				64.5	-10.5
1830/29	-6.4	63	3.79	2.38	-12.3	-12.5			59.5	-12.3
May										
1620/6	+8.0	33	10.7	3.55	-7.2	-7.2			77.0	-6.1

Fig. 1


Temperature of L.C.H. °F.
25
20
15
10
5
0
-5
-10
20
40
60
80
100
120
140
160
180
200
220
240
260
Time from start Minutes
Date :- 21 · 12 · 52.
Air Temperature :- - 27·0°C
Radiation Temperature with Hoar Frost Deposit :- - 28·0°C
Mean L.C.H. Reading :- + 16° F

MRP.983

Fig. 2 Calibration of Lithium Chloride Hygrometer.



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